

EXHIBIT 4

(12) **United States Patent**
Clark, Jr. et al.

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(45) **Date of Patent:** ***Jun. 13, 2017**

(54) **WALL RACER TOY VEHICLES**

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(71) Applicants: **Leonard R. Clark, Jr.**, Oreland, PA (US); **H. Peter Greene, Jr.**, Boyertown, PA (US)

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(72) Inventors: **Leonard R. Clark, Jr.**, Oreland, PA (US); **H. Peter Greene, Jr.**, Boyertown, PA (US)

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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This patent is subject to a terminal disclaimer.

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Primary Examiner — Tramar Harper

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(74) *Attorney, Agent, or Firm* — Mintz Levin Cohn Ferris Glovsky and Popeo, P.C.

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Related U.S. Application Data

(57) **ABSTRACT**

(60) Continuation of application No. 13/749,603, filed on Jan. 24, 2013, now Pat. No. 8,979,609, which is a (Continued)

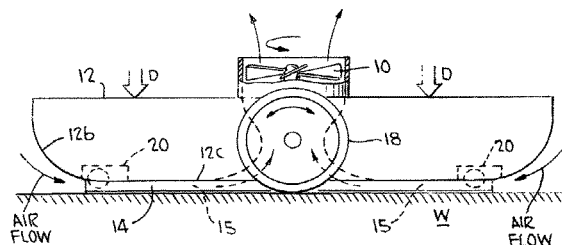
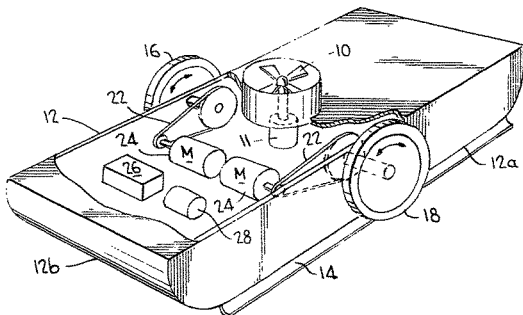
A motorized toy vehicle or Wall Racer that is capable of operating on vertical and inverted horizontal surfaces such as walls and ceilings, while being manufacturable at reasonable cost and operable on batteries having sufficient lifetime as to be enjoyable. One or more battery-powered fans draw air from around all or defined portions of the periphery of the chassis of the Wall Racer through a carefully-shaped duct, so that the air in the portion of the duct immediately adjacent the surface flows at high velocity and low pressure; the relatively greater pressure of the surrounding air urges the vehicle against the surface, allowing it to operate on vertical surfaces, such as walls, or inverted on horizontal surfaces, such as ceilings.

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A63H 30/04 (2006.01)
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(52) **U.S. Cl.**
CPC **A63H 17/262** (2013.01); **A63H 17/26** (2013.01); **A63H 30/04** (2013.01); **B62D 37/02** (2013.01); **B62D 57/024** (2013.01)

(58) **Field of Classification Search**
USPC 446/454
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23 Claims, 9 Drawing Sheets



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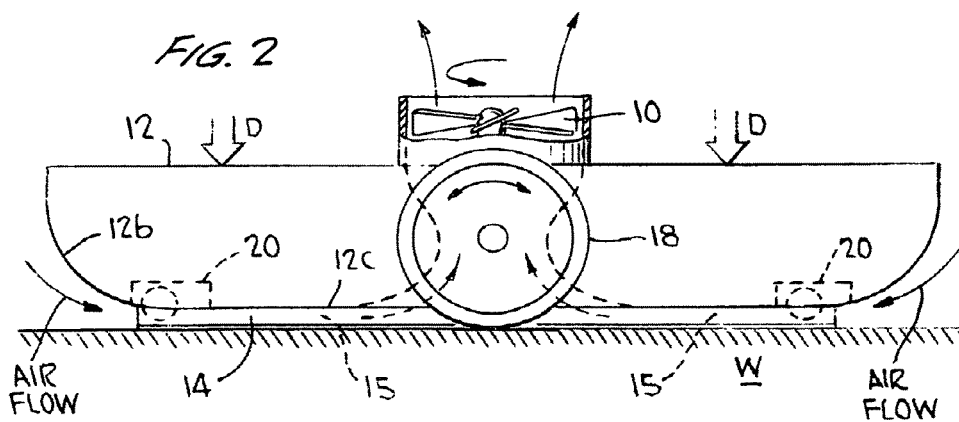
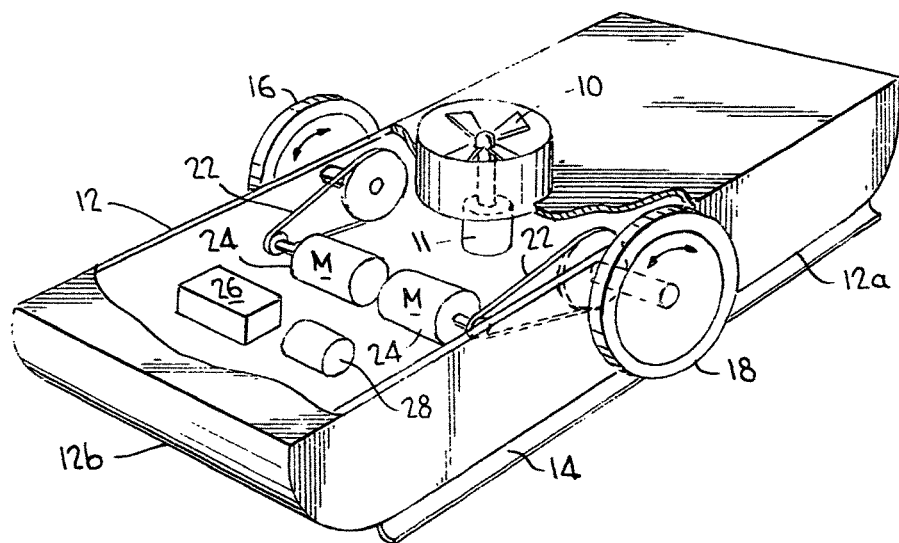
- continuation of application No. 13/137,064, filed on Jul. 19, 2011, now abandoned, which is a division of application No. 12/379,461, filed on Feb. 23, 2009, now Pat. No. 7,980,916, which is a continuation-in-part of application No. 11/177,428, filed on Jul. 11, 2005, now Pat. No. 7,753,755.
- (60) Provisional application No. 60/640,041, filed on Dec. 30, 2004.
- (51) **Int. Cl.**
B62D 37/02 (2006.01)
B62D 57/024 (2006.01)

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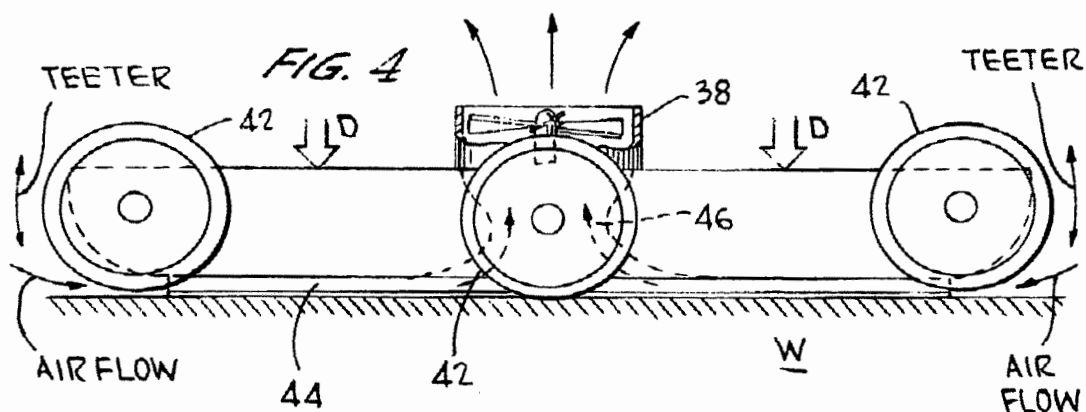
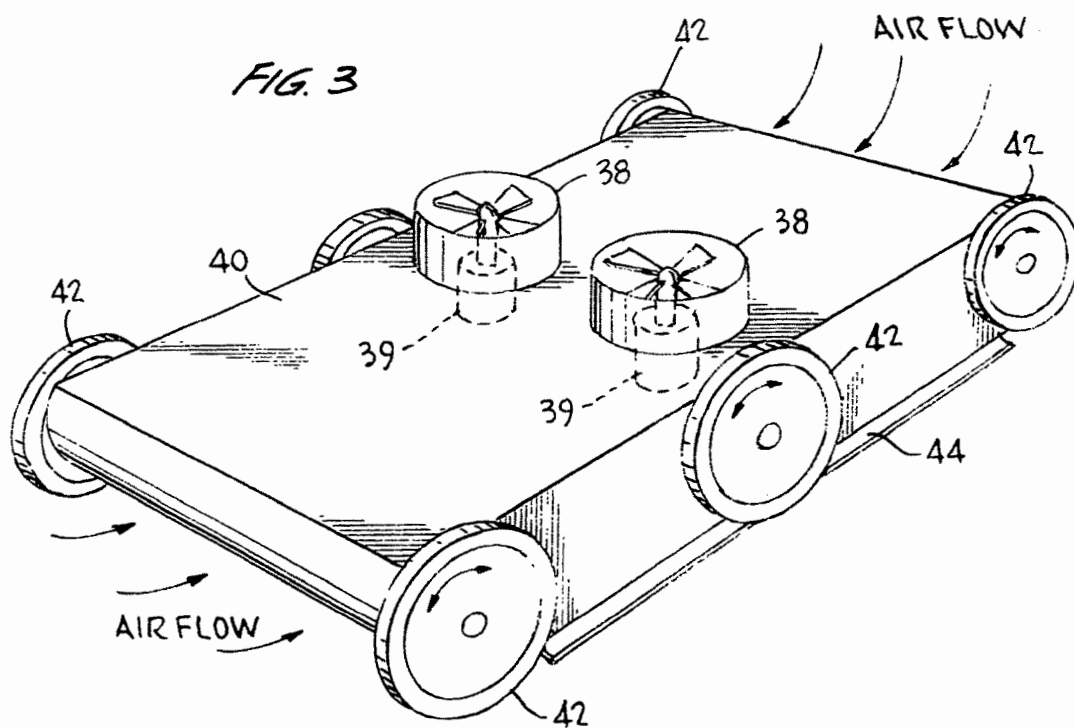
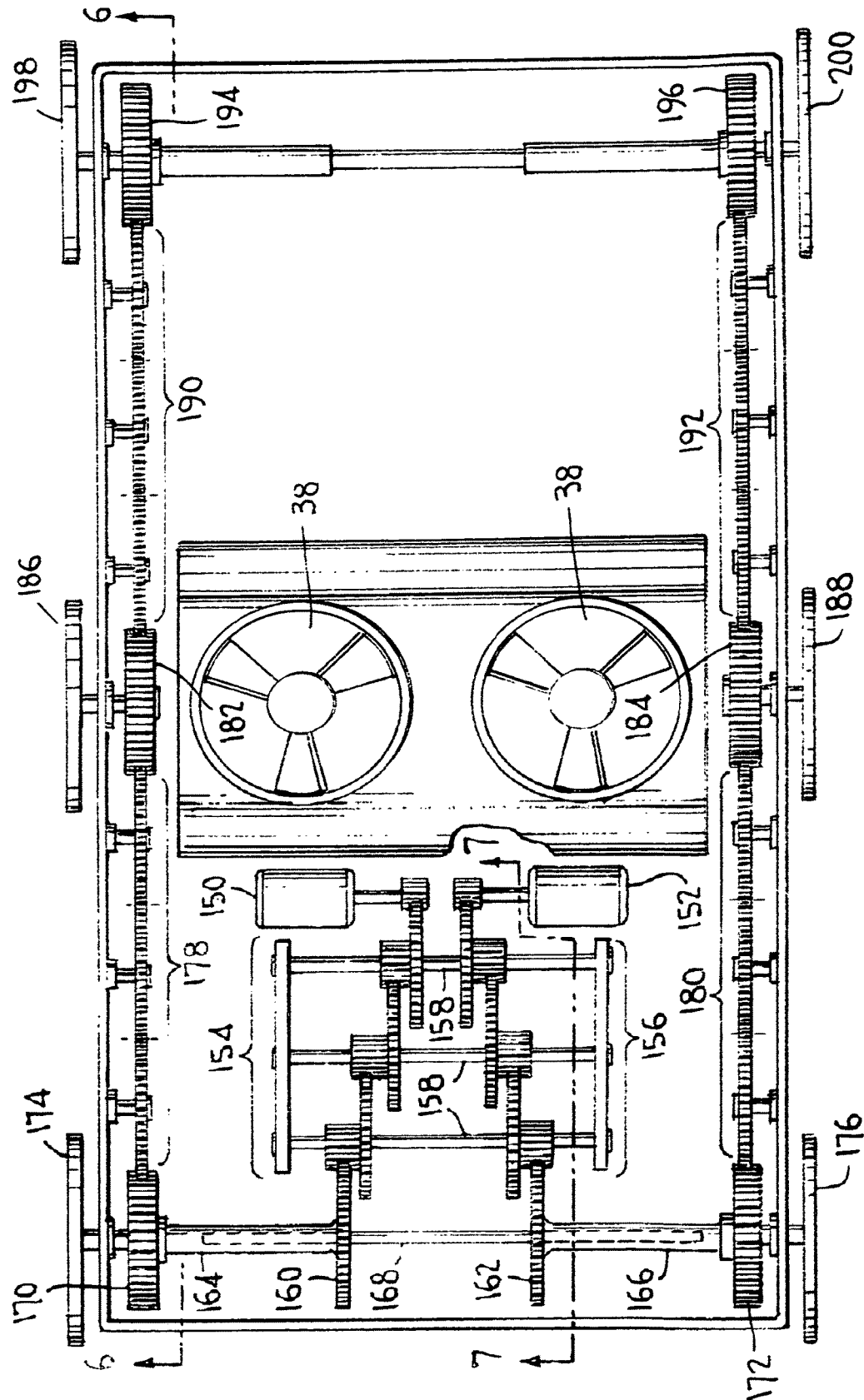
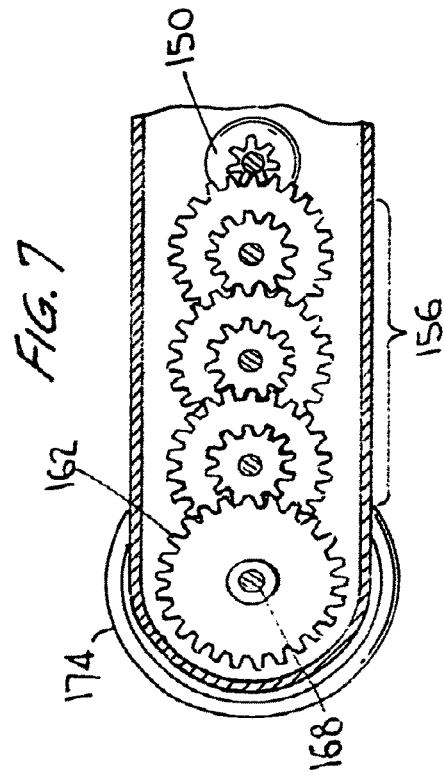
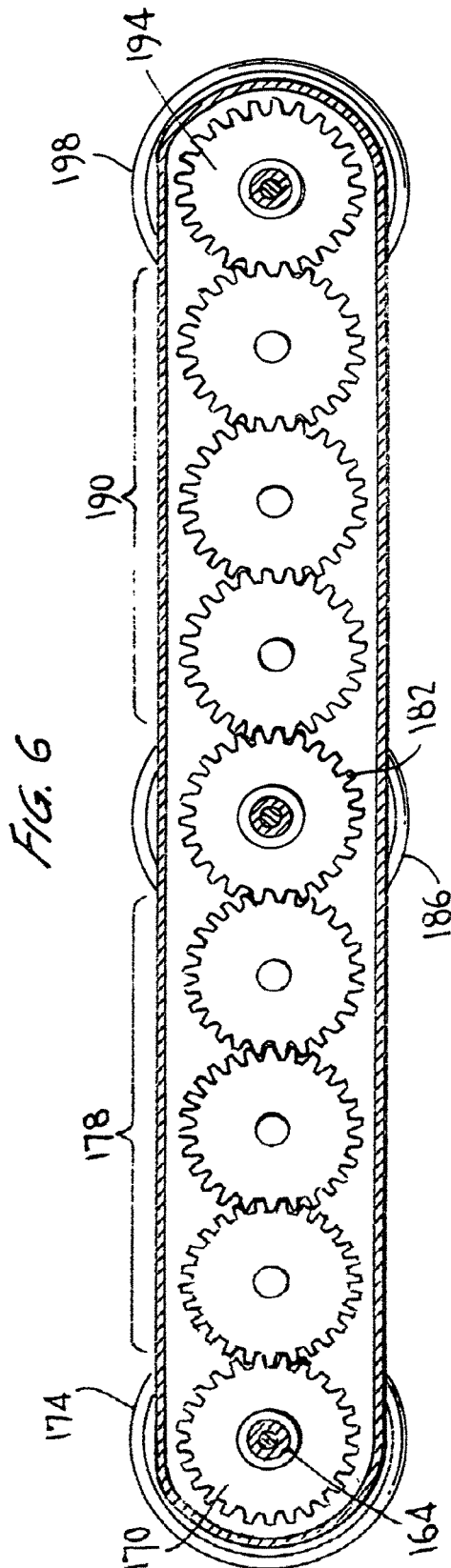


FIG. 5





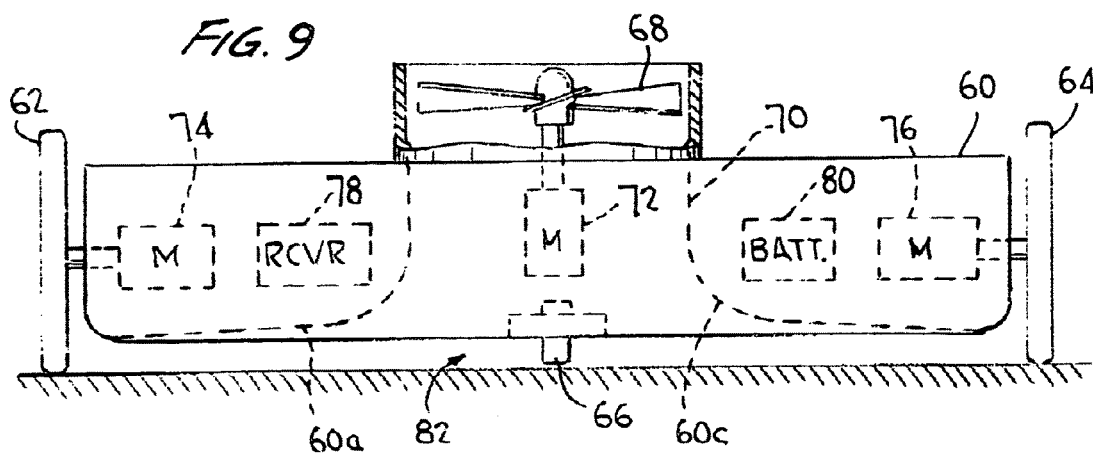
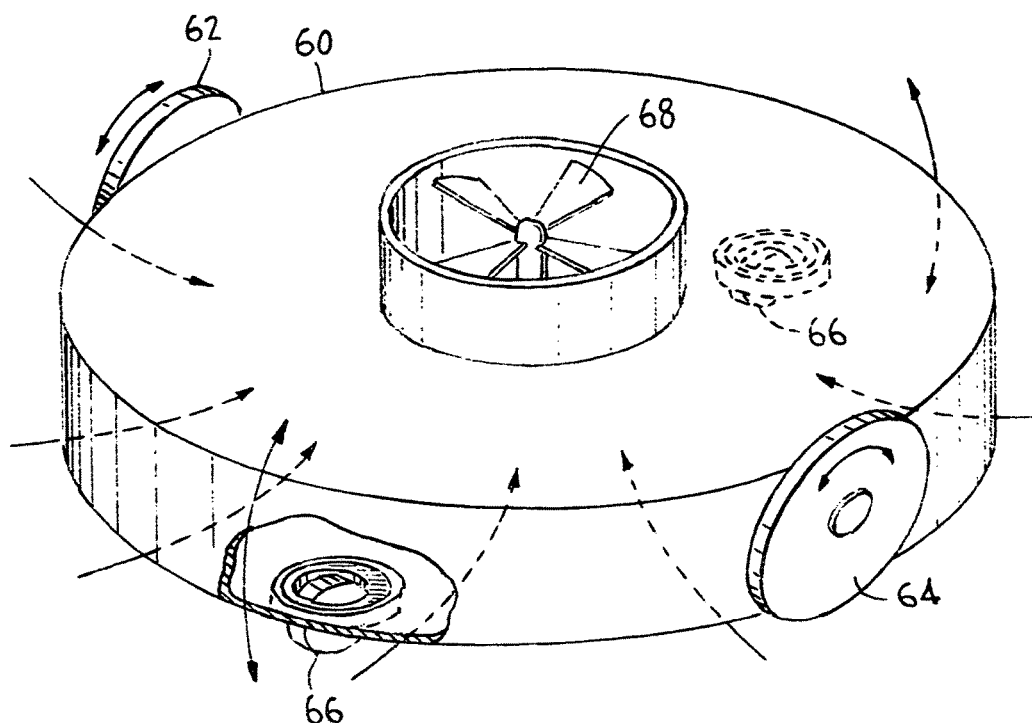


FIG. 10

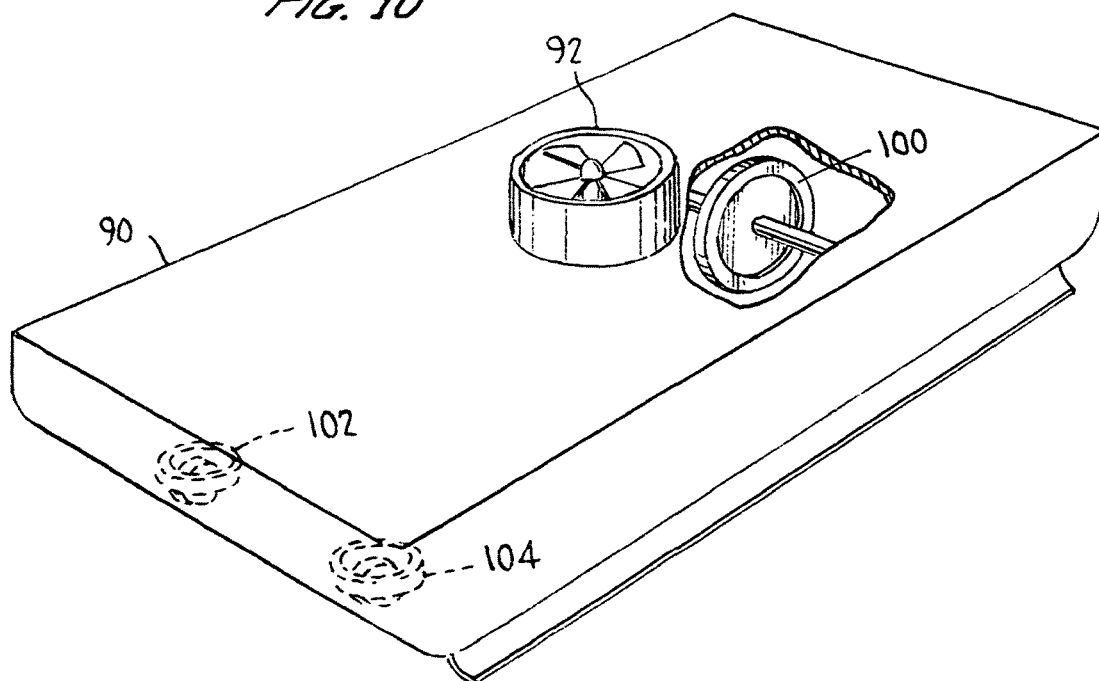
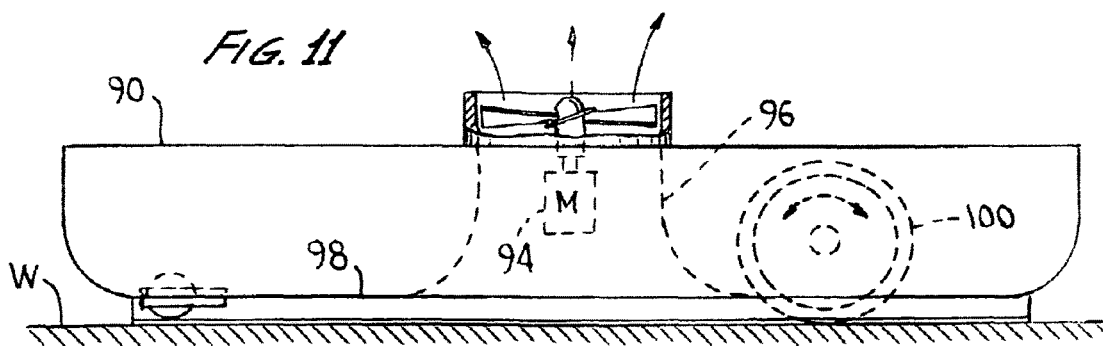
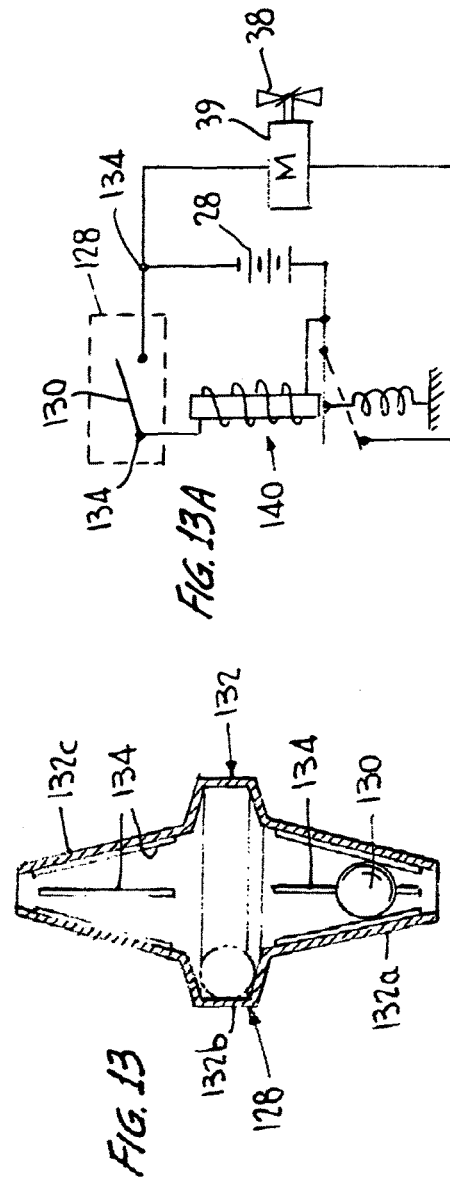
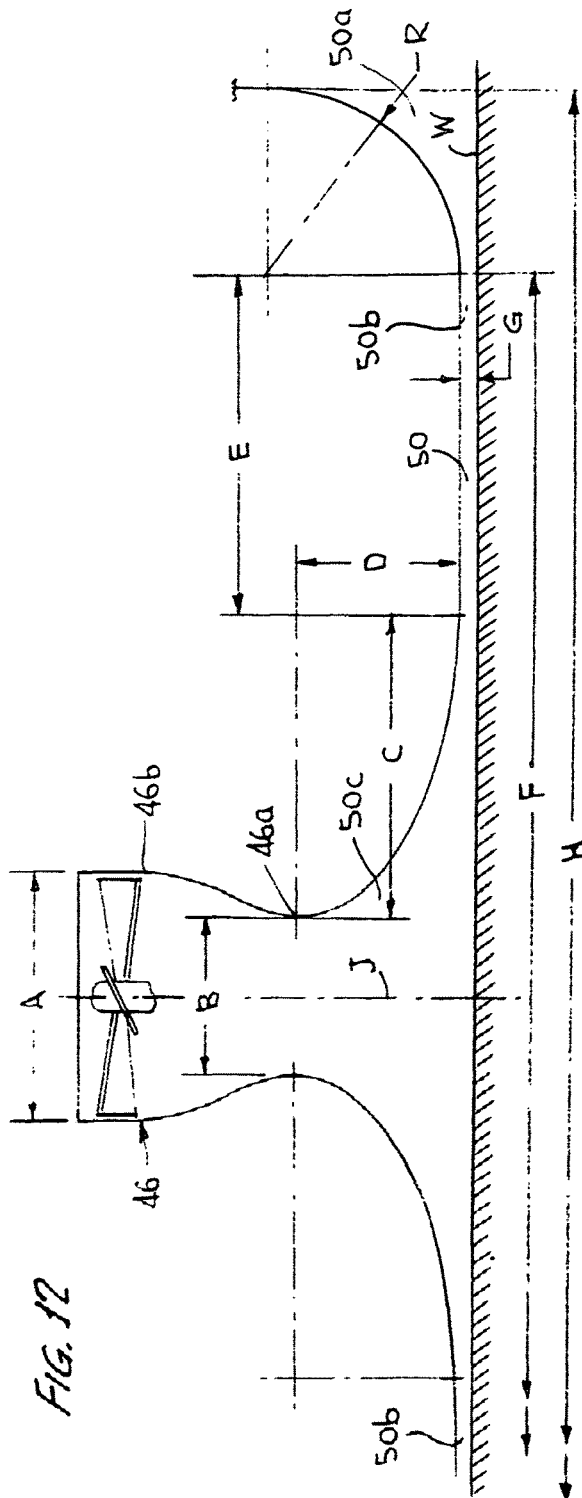
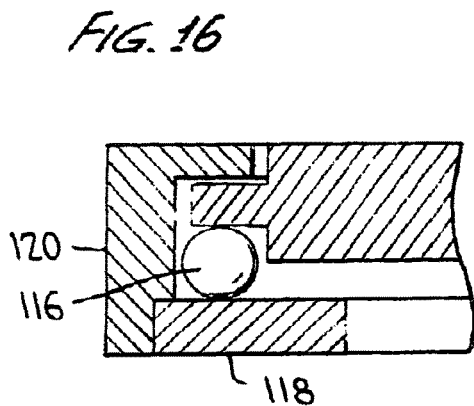
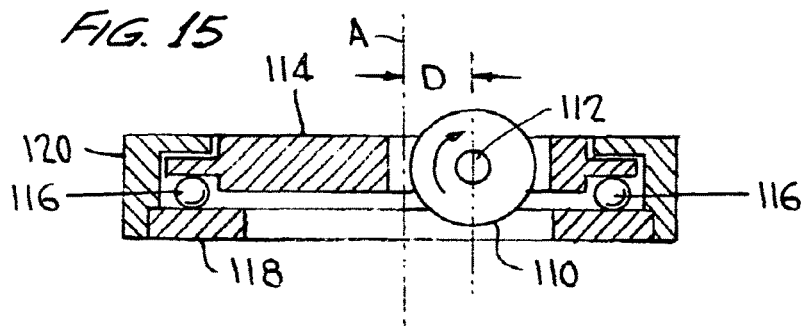
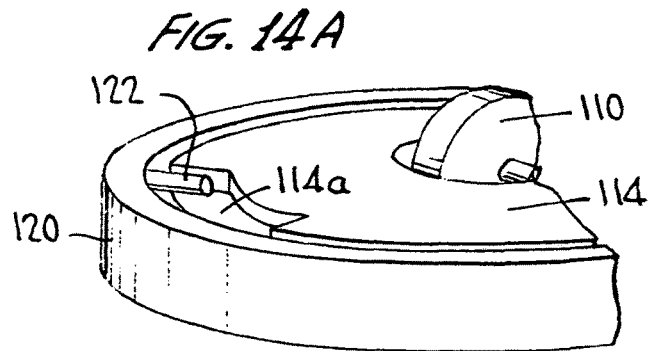
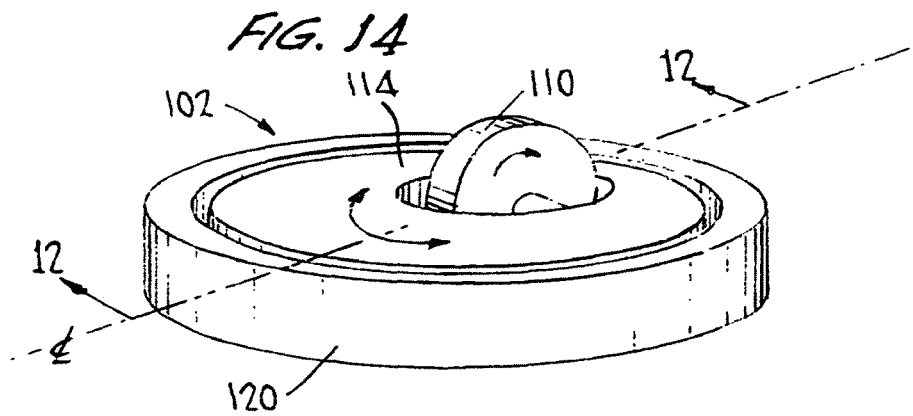
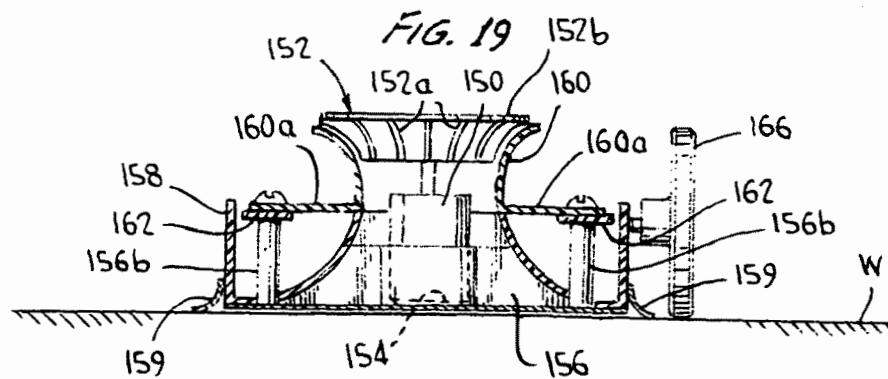
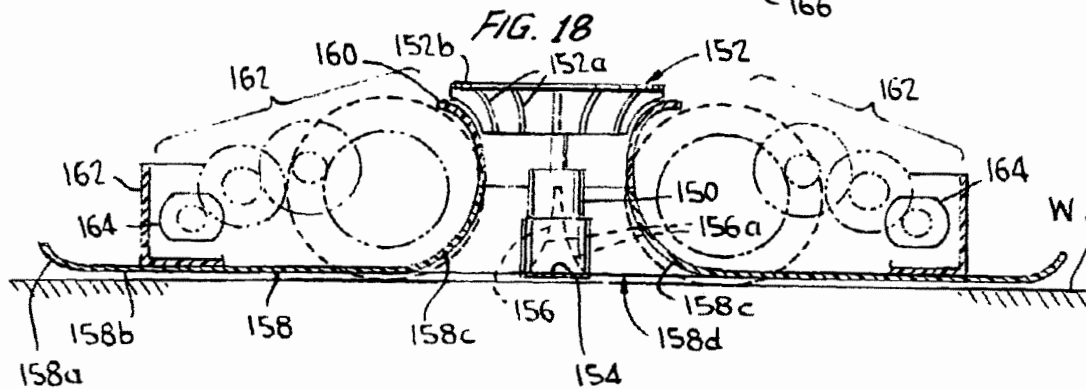
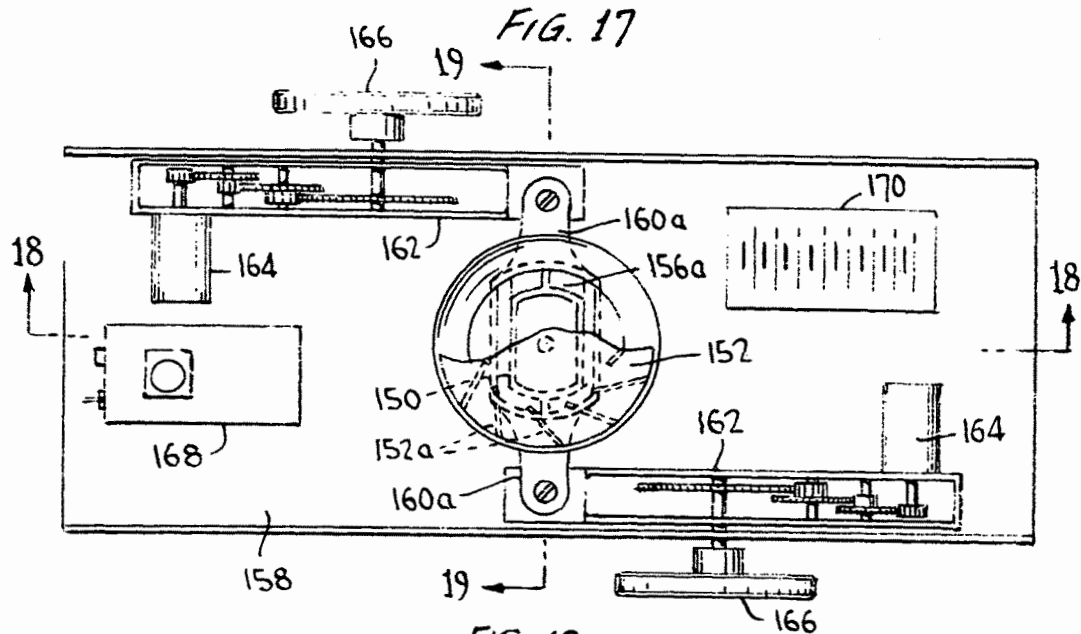


FIG. 11









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WALL RACER TOY VEHICLES**RELATED APPLICATION**

This patent application is a continuation of U.S. patent application Ser. No. 13/749,603, filed Jan. 24, 2013, which is a continuation of U.S. patent application Ser. No. 13/137,064, filed Jul. 19, 2011 and now abandoned, which is a divisional of U.S. patent application Ser. No. 12/379,461, filed Feb. 23, 2009 and now U.S. Pat. No. 7,980,916, which was a continuation-in-part of U.S. patent application Ser. No. 11/177,428, filed Jul. 11, 2005 and now U.S. Pat. No. 7,753,755, which claims priority to U.S. Provisional Application Ser. No. 60/640,041, filed Dec. 30, 2004. The U.S. patent application Ser. No. 12/379,461, filed Feb. 23, 2009 and now U.S. Pat. No. 7,980,916, also claims priority from U.S. Design patent application Ser. No. 29/312,447, filed Oct. 21, 2008.

FIELD OF THE INVENTION

This invention relates to radio-controlled motorized toy vehicles capable of operation on surfaces of all orientations, e.g., walls and ceilings as well as floors.

BACKGROUND OF THE INVENTION

Radio-controlled motorized toy vehicles, that is, vehicles driven by motors and steered responsive to commands transmitted remotely, are of course well-known. Toy vehicles that are very sophisticated in terms of their suspension and steering systems are available and are very popular. A toy vehicle that operated other than on essentially horizontal surfaces, e.g., which could operate on a vertical wall, or inverted on a ceiling, and which could be made and sold at a competitive price, would be very desirable.

U.S. Pat. No. 5,014,803 to Urakami shows a device for "suction-adhering" to a wall and moving along the wall, e.g., for cleaning the interiors of tanks and the like. The Urakami device relies on a relative vacuum; that is, air is drawn by a vacuum pump out from a sealed volume formed between the interior of the device and the wall, so that air pressure on the outer surface of the device forces it against the wall. This necessitates that an essentially air-tight seal be formed around the periphery of the device. Forming an air-tight seal between a moving device and a fixed surface is not a simple problem, and the Urakami patent is directed primarily to such seals. The obvious problems to be overcome are friction between the sealing member and the wall, which impedes motion of the device and causes wear of the sealing members, loss of vacuum at irregularities in the surface, and the large amount of power required to form an effective vacuum. This approach is not satisfactory for a toy vehicle that must be durable when operated by children and be able to be operated for a sufficiently long time with a limited amount of battery capacity to not frustrate the user.

SUMMARY OF THE INVENTION

The present invention provides a motorized toy vehicle that is capable of operating on vertical and inverted horizontal surfaces such as walls and ceilings, while being manufacturable at reasonable cost and operable on batteries having sufficient lifetime as to be enjoyable. The vehicle of the invention, referred to hereinafter as the Wall Racer, employs a freely-flowing stream of air between the surface-abutting periphery of the interior volume of the vehicle to

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create a pressure differential with respect to the surrounding air, so that the pressure of the surrounding air urges the Wall Racer against the surface.

More specifically, one or more battery-powered fans draw air from around all or defined portions of the periphery of the chassis of the Wall Racer through a carefully-shaped duct formed between the undersurface of the chassis and a juxtaposed surface, so that the air in the portion of the duct immediately adjacent the surface flows at high velocity. According to Bernoulli's Principle, this high-velocity air stream is of low pressure; the differential between this low-pressure air stream and the relatively greater pressure of the surrounding air urges the vehicle against the surface, allowing it to adhere to vertical surfaces, such as walls, or be operated inverted on horizontal surfaces, such as ceilings. The differential pressure thus urging the vehicle against the surface is referred to hereinafter, as in the automotive industry, as "downforce". Because the air stream must be freely flowing to attain high velocity, seals such as required for wall-climbing vehicles employing a vacuum (and which make it very difficult to provide workable vehicles, as above) are unnecessary. Indeed, entry of the air into the duct formed between the undersurface of the chassis and the juxtaposed surface is essential, and is controlled carefully to ensure stable, and insofar as possible non-turbulent flow.

It would be of self-evident amusement interest, or "toy value", to provide a radio-controlled vehicle capable of making the transition between operation on a floor to climbing a wall, and the Wall Racer in certain embodiments can do so. In order that the vehicle can make the transition, the fan(s) driving the air stream are actuated only when the vehicle begins to climb the wall.

Other inventive aspects of the Wall Racer will appear as the discussion below proceeds.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood if reference is made to the accompanying drawings, in which:

FIG. 1 and FIG. 2 show respectively a perspective view and an elevation in partial cross-section of a first embodiment of the Wall Racer;

FIG. 3 and FIG. 4 show respectively a perspective view and an elevation in partial cross-section of a second embodiment of the Wall Racer;

FIGS. 5, 6, and 7 show views of a gear train employed in the embodiment of FIGS. 3 and 4;

FIG. 8 and FIG. 9 show respectively a perspective view and an elevation in partial cross-section of a third embodiment of the Wall Racer;

FIG. 10 and FIG. 11 show respectively a perspective view and an elevation in partial cross-section of a fourth embodiment of the Wall Racer;

FIG. 12 shows a detailed diagram of one successful shape for the duct employed to form the high-velocity air stream, e.g., as employed in the second embodiment of FIGS. 3 and 4;

FIG. 13 shows a cross-sectional view of a switch employed to actuate the fans when the Wall Racer transitions from floor to wall operation, and which prevents its operation inverted on a ceiling, for safety reasons, while FIG. 13A shows a typical circuit in which it may be used;

FIGS. 14, 15, and 16 show respectively a perspective view, an elevation in partial cross-section, and an enlarged cross-section of a caster used in several of the embodiments

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of the Wall Racer, while FIG. 14A shows a partial view corresponding to FIG. 14, illustrating an optional variation; and

FIGS. 17, 18, and 19 show a further embodiment of the invention, wherein FIG. 17 is a schematic plan view, FIG. 18 a partial cross-section taken along the line 18-18 in FIG. 17, with certain components shown in dotted lines, and FIG. 19 is a partial cross-section taken along the line 19-19 in FIG. 17.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It will be apparent that one type of Wall Racer toy vehicle that would be desirably offered is one resembling an automobile, for example a race car, while other sorts of vehicles, such as trucks or military vehicles, e.g., armored tanks, might also be of interest. The first, second, fourth and fifth embodiments of the Wall Racer discussed herein are of generally elongated shape, so as to be fitted with model automobile bodies not otherwise contributing to the operation of the Wall Racer, while the third embodiment is circular and might be made to resemble a "flying saucer" type of space vehicle. All of these embodiments operate similarly, with differences as occasioned by the differing body shapes.

For example, FIGS. 1 and 2 show respectively a perspective and an elevation in partial cross-section of a first embodiment of the Wall Racer, which as noted is generally elongated and could readily be fitted with a model race car or other vehicle body (not shown). As mentioned above, in order that downforce urging the Wall Racer against an abutting surface W (hereinafter simply "the wall") can be developed, a high velocity stream of air is induced to flow in an underbody venturi duct formed between the undersurface of the chassis of the Wall Racer and the wall W. According to Bernoulli's Principle, as above, such a high velocity stream of air will be of reduced pressure with respect to the ambient air. The differential between this reduced pressure and the surrounding atmospheric pressure generates a resultant force D, termed "downforce" where, as here, its direction is such as to urge the vehicle "downwardly" toward the wall W. The amount of downforce D developed is proportional to the area over which the low pressure is created, and to the differential in pressure per unit area, so this area and the differential pressure must be adequate for the purpose.

Thus, as illustrated in FIGS. 1 and 2, a fan 10 is mounted in a fan duct extending through the chassis 12, and is driven by a battery-powered motor 11 so as to draw a high-velocity stream of air in from around at least a portion of the periphery of chassis 12. The stream of air flows through an underbody venturi duct 15 formed between the underside of chassis 12 and the juxtaposed surface of wall W, and is exhausted on the "upper" side of chassis 12, that is, on the side away from the abutting wall W. Downforce D is created as noted due to the differential in pressure between the low pressure of the high-velocity air stream in the underbody venturi duct and the ambient air; as noted, the total amount of downforce is proportional to the area over which the low pressure is developed, and to the differential in pressure at each point.

To maximize the area of low pressure by avoiding air being drawn in along the edges 12a of the chassis 12, that is, to ensure that the air stream is principally drawn in at the ends 12b of the chassis 12, flexible "skirts" 14 extend from the chassis 12 toward wall W and form a partial seal

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therebetween, limiting "short-cutting" of air from the sides of the chassis juxtaposed to the fan duct. The skirts thus define one or more, in this case two, sections of the periphery of the underbody of the chassis at which air is drawn into an entry portion of the underbody venturi duct, which directs airflow into the fan duct. Accordingly, air is drawn in primarily at the ends 12b, which are provided with a broad radius to ensure smooth and insofar as possible non-turbulent airflow; for similar reasons, the undersurface 12c of the chassis 12 is smooth. Thus the high-velocity air stream extends for a substantial portion of the overall length of the chassis, ensuring that adequate downforce is developed. In the absence of the skirts 14, air would tend to be drawn in along the sides of the chassis, limiting the area over which the reduced pressure is developed, and thus limiting downforce; there would likely also be considerable turbulence, further interfering airflow and reducing downforce.

In some circumstances, a further increase in downforce can be realized by limiting the clearance between the ends of the undersurface of the chassis and the wall surface, e.g., by providing downwardly extending baffles, akin to the side skirts 14 but extending only to the wall surface, that is, not intended to be drawn against the wall surface as are the side skirts 14. The reduction in intake area causes a further acceleration of the air flowing under these baffles, further reducing the pressure and increasing the downforce.

By comparison, in the generally circular third embodiment of the Wall Racer shown in FIGS. 8 and 9 (discussed further below) a substantial distance exists between all points on the outer periphery of the undersurface of its chassis and the centrally-located exhaust duct, so that the airflow in this embodiment is radially inwardly from all directions, the downforce is developed uniformly around the chassis, and no skirts need to be fitted.

As noted, the differential in pressure and thus the downforce developed is a function of the air velocity, which up to a point can be increased by reducing the cross-sectional area of the duct formed between the underside of the chassis and the wall W, that is, by reducing the ground clearance of the Wall Racer. However, if the cross-sectional area is reduced too much, turbulence will impede flow and reduce the desired effect; reducing the ground clearance would also increase the Wall Racer's sensitivity to surface irregularities and the like. No detailed theoretical calculations have as yet been carried out which would allow optimization of the effect sought. For example, by optimizing the duct design the current draw of the motor powering the fan inducing the flow could perhaps be reduced, increasing operating time per battery charge. Detailed specifications of the duct and other components employed in a successfully-tested embodiment of the Wall Racer are provided below.

Returning to discussion of the first embodiment of FIGS. 1 and 2, as illustrated the chassis 12 is supported by two opposed drive wheels 16 and 18, spaced transversely from one another on either side of the chassis near the midpoint thereof, and by opposed casters 20 (that is, devices comprising freely-rotating wheels mounted for pivoting about an axis perpendicular to their axis of rotation) at either end of the chassis 12. As indicated schematically by belt drives 22, the opposed drive wheels 16 and 18 are separately powered by motors 24 that are supplied with current by a battery pack 28 in response to control signals provided by radio-controlled receiver 26. The overall construction and operation of these components is conventional except as noted and will not be discussed in detail herein. Thus, if both motors are controlled to drive wheels 16 and 18 in the same direction, the Wall Racer moves in that direction, while turning is

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accomplished by driving the wheels **16** and **18** in differing directions or at differing rates. Casters **20** are unpowered, mounted on the longitudinal centerline of chassis **12**, and simply serve to maintain the correct spacing between under-surface **12c** of chassis **12** and wall **W**; preferred locations and design of casters **20** are discussed below.

The “differential” drive scheme shown is preferred over, for example, a conventional four-wheel chassis, with one pair of wheels powered and one pair steering, for the following reasons. In order that a vehicle can climb a vertical wall, sufficient downforce must be exerted, urging the vehicle toward the wall, not only to support the vehicle against the force of gravity but also to provide sufficient traction to propel the vehicle vertically against gravity. (By comparison, providing a vehicle that operates inverted on a ceiling is simplified, since it need only support itself and need not also climb vertically.) Ensuring good traction thus becomes paramount. So as to maximize the traction provided by the downforce available, the drive wheels are located centrally, at the center of the pressure exerted by the downforce, so that essentially all of the downforce is transmitted directly to the drive wheels, maximizing traction.

The casters **20** are preferably mounted so that both do not simultaneously touch a flat surface, so that a three-point support is always available, with the drive wheels **16** and **18** forming two of the three contact points. The motion thus provided, whereby the vehicle can rock slightly back and forth about the axis of the drive wheels **16** and **18**, as one or the other of casters **20** touches the wall **W**, is referred to as “teeter” herein. Thus the downforce is balanced over the central drive axle, which maximizes traction, while allowing the vehicle to be steered by differential driving of the opposed drive wheels **16** and **18**.

FIGS. **3** and **4** show a second embodiment of the Wall Racer; this embodiment appears likely to correspond to the earliest production version of the Wall Racer. FIG. **12** provides detailed dimensional information concerning this embodiment, and preproduction specifications are provided below as well.

As shown by FIG. **3**, in this embodiment two exhaust fans **38** are provided, spaced laterally from another on the transverse centerline of the chassis **40**, and each fan being driven by a motor **39** with the fan mounted directly on the motor shaft. Six drive wheels **42** are provided, three on either side of the chassis **40**, with the three wheels **42** on either side of the chassis being geared (or belt-driven) to one another so as to be driven in common by two separately radio-controlled motors. The radio control receiver and battery are not shown, as being generally within the skill of the art. FIGS. **5**, **6**, and **7** (discussed below) show a preferred gear train and motor arrangement. Thus, as in the FIG. **1** embodiment, steering is accomplished by differentially driving the wheels on either side of the chassis **40**. As shown, skirts **44** are again provided, so as to ensure that the airflow is primarily from the ends of the chassis to the fan exhaust duct **46**, in turn to ensure that an adequate area of high-velocity, low-pressure air flow is provided to generate adequate downforce. As illustrated by FIG. **4**, the center pair of wheels are slightly lower in the chassis than the end pairs, so as to provide “teeter” and ensure that the center pair of drive wheels are always in good contact with the wall **W**.

The pairs of wheels **42** at each end of the chassis are slightly proud of (i.e., extend slightly beyond) the respective ends of the chassis, so that as the vehicle approaches a wall while operating on a floor, the wheels contact the wall first. Thus providing the six-wheel arrangement of this embodiment allows the Wall Racer to make the transition from floor

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to wall in either direction. So that downforce urging the Wall Racer toward the floor does not prevent the Wall Racer from initially climbing the wall, the fans **38** are only energized when the chassis **40** reaches a predetermined inclination with respect to the horizontal. FIG. **13** shows a preferred switch, and FIG. **13A** a circuit, for controlling the fans accordingly.

As indicated above, FIGS. **5**, **6**, and **7** show a preferred arrangement of the two drive motors and corresponding gear trains for differentially driving the six wheels of the Wall Racer in its FIGS. **3** and **4** embodiment. FIG. **5** shows a plan view, and FIGS. **6** and **7** cross-sectional views along lines **6-6** and **7-7** respectively. Thus, assuming the Wall Racer is traveling toward the right in FIG. **5**, so that the upper side of the drawing is the “left”, and the lower the “right”, there are provided left-side and right-side drive motors **150** and **152** respectively. Motors **150** and **152** each drive reduction gear trains, **154** and **156** respectively; the gears of each are idlers, that is, spin freely on shafts **158**, so that gears from both trains can be supported on the same shafts **158** while turning independently of one another. The output gears of train **154** and **156** drive gears **160**, **162** respectively, which are fixed with respect to sleeve axles **164**, **166** respectively, riding on a fixed axle **168**, and thence to gears **170**, **172** respectively. Gears **170**, **172** are fixed to corresponding drive wheels **174**, **176**, and also drive further gear trains **178**, **180**, which drive central drive gears **182**, **184**, which are fixed to central drive wheels **186**, **188**. Central drive gears **182**, **184** also drive further gear trains **190**, **192**; these in turn drive gears **194**, **196**, to which are fixed wheels **198**, **200**. Implementation of this drive arrangement is within the skill of the art; while the gear trains and axles are shown as mounted on a metallic frame **202**, in production this chassis will typically comprise molded components.

It is also within the scope of the invention to employ a generally comparable arrangement to provide a four-wheel drive version of the vehicle of the invention, with differential steering as above. In this case one of the wheels might be mounted so as to spaced very slightly away from a plane contacted by the other three wheels; consequently the vehicle would “teeter” about an axis connecting the contact patches of the two of the wheels not diagonally opposite the wheel so spaced from the plane, so that either that wheel or the one diagonally opposite it would contact the plane. For example, if the left front (“LF”) wheel were slightly spaced from a plane contacted by the RF, LR, and RR wheels, the vehicle would teeter about an axis connecting the points at which the RF and LR wheels contact the plane, and the teeter would be limited by contact of either the LF or RR wheels with the plane. By comparison, if the wheels were located so as to simultaneously contact a flat plane, the vehicle would tend to be much more sensitive to any irregularities in the surface.

Implementation of differential steering of a four-wheel drive vehicle would not be unduly complex. By comparison, if steering were to be accomplished by pivoting of one or both pairs of wheels, this would involve additional complexity.

It is to be noted that a differential steering arrangement in a four-wheel drive vehicle with all four wheels in good contact with the surface would involve substantial resistance to steering due to “tire scrub”, that is, frictional resistance caused by the different effective turning radii of the “contact patch” of the tires on opposite sides of the vehicle. In general, to limit tire scrub within a given tire, relatively narrow tires are fitted to the drive wheels of the vehicles of the invention. Tire scrub becomes less significant as the

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overall size of the vehicle is reduced. To improve appearance, and to allow operation on thick carpets and the like, wider supplemental tires of slightly lesser diameter and formed of a lightweight foam or the like (not shown) can be assembled to the outer surfaces of the drive wheels.

As mentioned, FIG. 12 shows a detailed view of the underbody venturi duct 50 formed between the undersurface of chassis 40 and a juxtaposed surface, such as a wall W. This embodiment of the underbody was employed in one successfully-tested version of the second embodiment of the Wall Racer of the invention, as shown in FIGS. 3 and 4. FIG. 12 further provides reference to dimensional details of the chassis 40. In this version, the overall chassis length H is 11.828", with six wheels of 2.524" diameter; the wheelbase F of the outer pairs of wheels is 9.50", so that the wheels are proud of the chassis, i.e., extend slightly beyond the end of the chassis 40, in order to engage a vertical surface and thus enable the Wall Racer to climb a wall from the floor. The center axle is 0.050" closer to the wall W than the end pairs of wheels, so that the desired "teeter" is provided.

The underbody venturi duct 50 is longitudinally symmetric about a centerline J, with one end only shown in detail by FIG. 12. As shown in detail by FIG. 12, each "half" of the underbody duct 50 formed between the undersurface of the chassis 40 and the wall W comprises an entry portion 50a, a transition portion 50b, and an exit portion 50c, which makes a smooth transition into a fan duct 46, also of venturi shape, in which the fan(s) are located. Air enters each half of the underbody venturi duct at an inlet opening at the periphery of the chassis 40, defined by the entry portion 50a of underbody venturi duct 50. Entry portion 50a is defined by a radius R formed on the end of the chassis; in the version shown, this radius is 1.164". The axles of the front and rear pairs of wheels lie on the center of this radius, and are slightly larger in radius, so that each tire's rolling surface is somewhat proud of the chassis end, as noted. Entry portion 50a is faired into and connects smoothly with an extended flat transition portion 50b formed by a flat surface on the underside of the chassis; since the duct 50 formed between the underside of chassis 40 and the wall is of minimum cross-sectional area in this region, the maximum air flow velocity, and accordingly the maximum downforce per unit area, are developed here.

The goal in designing the underbody venturi duct 50 is to maximize the extent of the region of minimum cross-sectional area, while optimizing its cross-sectional dimension, so as to provide smooth, preferably non-turbulent flow into and out of this region, all in order to maximize flow velocity. To ensure smooth flow, the section of the undersurface of chassis 40 defining the upper bound of entry portion 50a is radiused, and the corresponding section defining the upper bound of exit portion 50c describes a portion of an ellipse. In the successfully-tested version depicted, this elliptical contour was drawn using a 2"x4" ellipse as found on a draftsman's "30-degree" template; that is, dimensions D and C are 1" and 2", respectively. As illustrated, then, the extent E of flat portion 50b is 2.25" long, forming a "tunnel flat". With the vehicle balanced on the center pair of wheels, so that the flat portion 50b is parallel to the wall, the ground clearance G therebetween is 0.098". Flat portion 50b makes a smooth transition to exit portion 50c, which as noted is 2.00" long and elliptical in longitudinal cross-section. Exit portion 50c in turn makes a smooth transition to a central venturi section 46a of fan duct 46, in which the fan(s) are located. In the two-fan embodiment of FIGS. 3 and 4 and detailed in FIG. 12, the longitudinal dimension B of the narrowest portion of this venturi

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section 46a is 1.00"; section 46a extends across the chassis 50 so as to form a transverse "mail slot". As it extends away from the wall, the mail slot section 46a then broadens out gradually in the longitudinal direction and is divided along the longitudinal centerline to form two circular-section ducts 46b in which the fans 38 are located; their diameter, dimension A, is 1.625".

The following are the principal specifications of a successfully-tested version of the Wall Racer, as shown in FIGS. 3 and 4 and dimensioned as in FIG. 12:

- Wheelbase (dimension F) 9.5" (front to rear axle)
- Track width 5.8" (centerline to centerline, at contact points)
- Underbody duct width 4.9" (between skirts)
- Chassis weight 584 g.
- Body weight 29 g.
- Total weight 613 g.
- Weight distribution (without body, center axle unsupported):
 - Front axle 260 g (44.5%)
 - Rear axle 324 g (55.5%)
- Ground clearance (dimension G) 0.098"
- Motor voltage 6 v. nominal (five 1.2 v. 1000 mah NiMH cells)
- Downforce fans current draw 4 amperes total
- Ducted fans (two)—1.625" diameter, 3 blades
- Total net downforce 1280 g.
- Teeter (center axle offset) 0.050"
- Fan RPM 30,000

The chassis itself can be molded of a lightweight foam material, having its undersurface shaped to define the venturi duct 50 in cooperation with the surface of the wall W. It is convenient to mount the components, such as bearings for the axles carrying the wheels, drive motors and gear or belt drive components, radio control receiver, batteries, and motor and fan assemblies, in recesses molded into the foam of the chassis. In particular, the fan assemblies may alternatively comprise hard plastic molded ducts within which the fan and drive motor are retained; the exit portion of the underbody venturi duct is then shaped to mate smoothly therewith.

In a successfully-tested prototype, the skirts 44 (FIG. 3) were formed of "Tyvek" spunbonded nonwoven olefin envelope material sized and located so as to curve outwardly at a nominal 45 degrees when in contact with the wall; a stiffening strip of plastic glued to the lower edge of the skirts, but spaced slightly therefrom, may be desirable to prevent local buckling.

Given the above detailed disclosure of the invention, those of skill in the art would have no difficulty in its practice. In particular, it will be appreciated that batteries (exemplary specifications being provided above) must be provided to power the fans and the drive wheels, that the drive wheels, three on each side in the embodiment of FIGS. 3 and 4, must be linked to one another and to the respective drive motor by gears, as illustrated in FIGS. 5, 6, and 7, or by belts or other means, and that the motors must be individually controllable by signals provided by an operator by way of a radio or infrared transmitter and receiver pair. These aspects of the implementation of the invention are within the skill of the art. It is also within the scope of the invention to drive each of the six wheels individually, that is, to eliminate the gear or belt arrangement in favor of separate motors for each wheel, but this alternative is considered undesirable as it would involve a weight penalty.

FIGS. 8 and 9 show as mentioned a third version of the Wall Racer, in this case with a circular chassis 60 to provide

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a “flying saucer” appearance. In this version, two drive wheels **62** and **64** are provided on diametrically opposed points on the chassis **60**, with casters **66** on opposite sides, along a line perpendicular to the axis of the drive wheels **62** and **64**. The casters may be raised slightly from a plane including both drive wheels and the casters, to provide “teeter” as above. (It will be apparent that this version of the Wall Racer cannot negotiate the transition between floor and wall.) Downforce is provided by a centrally-located fan **68** disposed in a venturi duct **70** and driven by a motor **72**. Drive wheels **62** and **64** are individually driven by motors **74** and **76** responsive to control signals from a radio-control receiver **78** and powered by battery **80**.

In this version, as mentioned above, the exhaust duct **70** is equidistant from all points on the periphery of chassis **60**, so that the inward air flow path is of equal length at all points around the chassis **60**. Hence there is no need for skirts, and the air flow is radially inward all around the periphery. Again, a radius is provided around the periphery of the lower edge of chassis **60**, as illustrated at **60b**, so that the inlet opening of the underbody venturi duct extends circumferentially around the chassis, and a large-radius or elliptical transition portion **60c** is provided where the underbody duct **82** meets the exhaust duct **70**, to ensure smooth and substantially non-turbulent airflow. The transition portion of the underbody duct **82** formed between the underside **60a** of chassis **60** and the wall is preferably shallow and substantially conical in section, as illustrated, so that the cross-sectional area of the duct **82** stays constant as its radius from the center of exhaust duct **70** varies; in this way the velocity of the inward-flowing air stream and the differential pressure exerted thereby are both substantially constant, so that the downforce is exerted evenly at substantially all points on the chassis **60**, that is, outside of duct **70**.

FIGS. **10** and **11** show a further version of the Wall Racer, again having an elongated chassis **90** suitable for mounting of a model race car body or the like. In this embodiment, a single fan **92** is located centrally on the chassis, is driven by a motor **94**, and is disposed within an exhaust duct **96** communicating with an underbody venturi duct **98** formed between the underside of chassis **90** and the wall **W**. The underbody duct **98** is designed generally as discussed above with respect to FIG. **12**.

In this embodiment, a single drive wheel **100** driven by a motor powered by a battery and responsive to control signals provided by a radio control receiver (none of the unnumbered components being shown) is located on the vehicle’s longitudinal centerline, near the center of effort of the downforce, but disposed toward one end of the chassis so as not to interfere with the exhaust duct **96**. Two casters **102** and **104** are mounted at the opposite end of the chassis **90**. Caster **102** is free to pivot about an axis perpendicular to wall **W**, while caster **104** is also pivoted about a similarly perpendicular axis, but only between angular limits (see FIG. **14A**, below).

Thus, chassis **90** rests on a tripod comprising drive wheel **100** and casters **102** and **104**. If drive wheel **100** is driven so as to propel the vehicle toward the direction of the end of the chassis on which drive wheel **100** is disposed, that is, rightwardly in FIG. **11**, the casters trail behind, and the vehicle travels in a straight line; if drive wheel **100** is driven in the opposite direction (counterclockwise in FIG. **11**), the caster **104** provided with angular stops rotates about the axis perpendicular to wall **W** until its pivoting is stopped at one or the other of its angular limits, so the vehicle turns in one direction until the direction of travel is reversed. Hence directional control of the Wall Racer in this embodiment is

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substantially constrained; being greatly simplified, this embodiment might be best suited to a low-cost version of the invention.

As mentioned, FIGS. **14-16** show respectively a perspective view, a cross-section, and an enlarged partial cross-section of a caster **102** used in several of the embodiments of the Wall Racer, while FIG. **14A** shows a partial view corresponding to FIG. **14**, illustrating a optional variation. In these views, the caster **102** is shown inverted, that is, with its face which would be juxtaposed to wall **W** oriented “up” in the drawings. A roller **110**, which contacts wall **W**, is carried by an axle **112** that is mounted for rotation in a rotating plate **114**; plate **114** rotates about an axis **A** perpendicular to but offset from that defined by axle **112**. In the embodiment shown, rotating plate **114** in turn rides on a number of balls **116**, which bear against a closure ring **118**; closure ring **118** is secured to a frame **120**, which can be mounted to the chassis. Thus, roller **110** engages the wall, and rotates about axle **112** as the vehicle is maneuvered; the assembly of roller **110**, axle **112** and plate **114** can rotate with respect to frame **120** and thus with respect to the vehicle chassis, as the latter is steered. The axle **112** is offset with respect to the axis **A** about which plate **114** rotates, so that as the vehicle is steered, plate **114** rotates and roller **110** trails the axis **A** of rotation of plate **114**.

If it is desired to restrict the rotation of plate **114**, e.g., as discussed above with respect to the version of the Wall Racer shown in FIGS. **7** and **8**, so as to provide some turning, albeit not precisely controlled, this can be accomplished as shown, for example, in FIG. **14A**. As illustrated, a pin **122** extends through and is retained in the upper flange of frame **120** and fits within an angular recess **114a** formed in the upper surface of rotating plate **114**, limiting the degree of rotation about axis **A** that is permitted to plate **114**.

As mentioned, in the embodiments of the Wall Racer in which it is capable of operation on a floor and climbing onto a wall (that is, the embodiment of FIGS. **3-7**), it is desired to provide a switch that actuates the exhaust fan(s) only when the Wall Racer reaches a desired angle, typically between 30 and 60 degrees with respect to the horizontal, so that downforce does not prevent the vehicle from beginning to climb the wall as the wheels engage the wall’s surface. FIG. **13** shows a switch **128** for so doing, and which also de-energizes the fan if the Wall Racer is placed upside-down, against a ceiling; this may be preferred for safety reasons, so that the Wall Racer cannot fall on anyone. FIG. **13A** shows a typical circuit in which switch **128** may be used.

Switch **128** comprises an electrically conductive metal ball **130** disposed within a hollow nonconductive switch body **132**. Body **132** is symmetrical about a vertical axis, and defines a generally frusto-conical lower portion **132a**, in which ball **130** rests when the vehicle is on the floor, as shown in full, a disc-shaped central portion **132b**, into which the ball falls, as indicated in dotted lines, when the vehicle begins to be oriented vertically, as when it begins to climb a wall, and a generally frusto-conical upper portion **132c**, in which ball **130** falls if the Wall Racer is placed inverted against a ceiling. Conductive contacts **134** are disposed on the inner surfaces of lower portion **132a** and upper portion **132c**, so that when ball **130** is disposed in either the upper or the lower portions, it connects the contacts **134**.

As shown in FIG. **13A**, contacts **134** (two of which are connected in common) are wired in series with a normally-open relay **140** and battery **28**, which controls a circuit including battery **28** and fan motor **39**. Thus, with switch **128** closed, that is, with the Wall Racer essentially horizon-

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tal, and ball **130** making the connection between contacts **134**, relay **140** is closed, as shown; when the Wall Racer leaves the horizontal sufficiently that ball **130** falls out of lower section **132a**, into upper section **132b**, relay **140** opens, closing the motor circuit and energizing motor **39**, so as to drive fan **38**. In this embodiment, if the Wall Racer is placed inverted against a ceiling, ball **130** falls into upper portion **132c**, similarly connecting contacts **134**, and preventing operation of fan motor **39**.

As mentioned, FIGS. **17-19** show a further embodiment of the invention. The principal improvements provided by this embodiment with respect to those discussed above are the provision of a radial-flow fan rather than the axial-flow fan(s) shown in the previous embodiments, provision of two drive wheels offset longitudinally from one another, principally for reasons of packaging convenience, and elimination of the casters or other wheels in favor of allowing the undersurface of the chassis to touch the wall.

Thus, as shown in FIGS. **17-19**, a fan motor **150** drives a radial-flow fan **152**, that is, comprising a circular end plate **152b** and vanes **152a** that are generally perpendicular to the end plate and angled with respect to the axis of rotation. Air is drawn in along the axis, that is, flowing upwardly around motor **150**, and is exhausted radially outwardly. The radially outward ends of vanes **152a** are curved so as to be closely juxtaposed to a diffuser or fan duct **160** defining a generally bell-shaped interior surface, for efficiency in use. Motor **150** is received in a recess **154** in a transverse member **156**. Member **156** extends transversely across chassis **158**, filling the central portion of a transverse "mail slot" **158d** in chassis **158**.

Generally as discussed above in connection with FIG. **12**, and as shown by FIG. **18**, chassis **158** is radiused at **158a** to define entry portions of the underbody venturi duct, is flat at **158b** to provide the transition portions thereof, and defines a smooth duct at **158c** to define the exit portions thereof. Skirts **159** are again provided to prevent air entry along the long sides of the chassis **158**. On either side of the motor-receiving recess **154**, member **156** is shaped as indicated by dashed lines **156a**, in order to provide a fair flow path for air drawn in at the ends of chassis **158**. The exit portions of the venturi duct as formed by chassis **158** at **158c** mate with diffuser duct **160**, the inside surface of which is generally bell-shaped so as to be closely juxtaposed to vanes **152a** of fan **152**, as noted above. As also shown, assembly is simplified by formation of transversely-extending ears **160a** on diffuser duct **160**. Ears **160a** mate with posts **156b** formed on transverse member **156**, as shown in FIG. **19**; fasteners passing therethrough also secure gearboxes **162**, which are discussed further below.

Propulsion for the vehicle is provided by two motors **164**, which drive two drive wheels **166** through reduction gearboxes **162**, as mentioned above. As previously, motors **164** are controlled responsive to radio, or preferably, infrared signals transmitted by a remote transmitter (not shown) and received by a receiver **168**. Power for motors **164** as well as for fan motor **150** is provided by a battery **170**. Electrical connection between these components, provision for battery charging, on-off switching, mechanical details such as the construction of gearboxes **162**, selection and operation of receiver **168**, and the control of motors **164** responsive to the received signals are within the skill of the art and need not be detailed here.

As illustrated, drive wheels **166** are offset longitudinally with respect to one another, and no casters are provided. The axes of drive wheels **166** are located with respect to the bottom surface of chassis **158** such that the flat central

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portion **158b** of the chassis is spaced on the order of 0.020" from the wall surface W. Consequently, the chassis **158** "teeters", that is, pivots very slightly about a diagonal axis extending between the points at which drive wheels **166** contact the wall surface W, such that in use the teeter or pivoting is limited by undersurface of the chassis **158** contacting the wall surface W at one or the other diagonal corner. The undersurface of chassis **158** is made smooth to reduce friction between it and the wall surface W as the vehicle is propelled. Slight "bumps" might also be formed at the diagonal corners of the chassis, to localize the contact between the chassis and wall surface W. It is found that the friction experienced in use of the toy of the invention with walls and other surfaces of typical smoothness—e.g., conventionally painted interior walls—is sufficiently small as to present no difficulty, and likewise that the slight asymmetry in the airflow path under the chassis presents no difficulty.

Thus, in use, the fan **152** is energized and the vehicle is placed against a surface W. Air drawn by fan **152** passes inwardly from the ends of the chassis **158**, up through the venturi tunnel collectively formed by the mail slot **158d** in the chassis **158**, transverse member **158**, and diffuser duct **160**, and exits fan **152** in the radially-outward direction. Downforce is thereby created, pulling the vehicle toward the wall surface W. Motors **164** can then be differentially activated to propel the vehicle in any desired direction.

While several preferred embodiments of the invention have been disclosed herein in detail, the invention is not to be limited by the disclosed embodiments, which are exemplary only.

What is claimed is:

1. A toy vehicle comprising:

a chassis comprising an undersurface, the chassis configured to mount on at least one wheel that is configured to move on a surface;

a first motor configured to drive the at least one wheel; and

a second motor configured to drive a fan that is configured to draw air from a duct between the undersurface and the surface into a fan duct, the duct comprising an entry portion, an exit portion connected to the fan duct, and a flat transition portion between the entry portion and the exit portion, the duct being structurally smooth from the entry portion to at least a location vertically below the fan duct when the toy vehicle is placed on ground.

2. The toy vehicle of claim 1, wherein the chassis further comprises skirts extending from at least two opposite sides of the undersurface.

3. The toy vehicle of claim 2, wherein the chassis is elongated such that a length of the chassis in a longitudinal direction is more than a length of the chassis in a latitudinal direction.

4. The toy vehicle of claim 3, wherein the skirts extend from sides of the chassis such that the skirts provide at least a partial seal between the undersurface and the surface.

5. The toy vehicle of claim 4, wherein the skirts extend from all four sides of the chassis.

6. The toy vehicle of claim 1, wherein the surface is a vertical surface.

7. The toy vehicle of claim 1, further comprising:

a receiver that receives a control signal from a transmitter that is wirelessly connected to the receiver, the first motor receiving current from the battery when the receiver receives the control signal from the transmitter.

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8. The toy vehicle of claim 1, wherein the at least one wheel comprises two wheels disposed on opposite sides of the chassis.

9. The toy vehicle of claim 8, wherein:

the first motor comprises two motors that operate in response to signals from a receiver; and

the two wheels are driven differentially by the two motors.

10. The toy vehicle of claim 8, wherein a pair of bumps on the undersurface are displaced longitudinally with respect to one another.

11. The toy vehicle of claim 10, wherein the two wheels and only one bump of the pair of bumps contacts a flat surface at any time.

12. The toy vehicle of claim 11, wherein the chassis pivots along a line connecting points where the two wheels contact the surface.

13. The toy vehicle of claim 1, wherein the at least one wheel comprises two wheels disposed on at least two opposite sides of the chassis, wherein a first wheel of the two wheels is displaced longitudinally with respect to a second wheel of the two wheels.

14. The toy vehicle of claim 1, wherein the fan is a radial-flow fan.

15. The toy vehicle of claim 1, wherein the first motor and the second motor receive current from a single battery.

16. The toy vehicle of claim 1, wherein an area of the undersurface is more than an area of the fan duct.

17. The toy vehicle of claim 1, wherein a pressure difference between a pressure of the air flowing into the fan when the fan is operational and a pressure of ambient air induces a force urging the chassis towards the surface.

18. The toy vehicle of claim 1, wherein:

a connection between the entry portion and the flat transition portion is structurally smooth;

a connection between the flat transition portion and the exit portion is structurally smooth; and

a connection between exit portion and the fan duct is structurally smooth.

19. The toy vehicle of claim 1, wherein the duct elongates for at least a length of the undersurface.

20. The toy vehicle of claim 1, wherein the duct is a venturi duct.

21. A toy vehicle comprising:

a chassis comprising an undersurface;

at least one wheel operatively coupled to the chassis and configured to move on a surface;

a fan connected to a fan duct to receive free flowing air drawn in by a duct that is connected to the fan duct and is located between the undersurface and the surface, the receiving of the air by the fan inducing a downforce urging the chassis towards the surface, the duct com-

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prising an entry portion configured to receive a free flow of the air, a transition portion configured to transport the air, and an exit portion configured to exit the air to the fan duct, the duct being structurally smooth from the entry portion to at least a location vertically below the fan duct when the toy vehicle is placed on ground; and

a power source to drive the fan to induce the downforce urging the chassis towards the surface.

22. The toy vehicle of claim 21, wherein:

the chassis comprises skirts extending from all four sides of the chassis;

the fan is initiated when a switch is activated; and

the at least one wheel comprises a first wheel and a second wheel, the first wheel being displaced longitudinally with respect to the second wheel, the first wheel and the second wheel being configured to be steered by a remote transmitter.

23. A battery powered, remotely-controlled toy vehicle configured for operation on a surface, comprising:

a chassis having an undersurface and having flexible skirts extending along at least two opposite sides of the undersurface of the chassis;

at least one wheel mounted on the chassis;

a receiver responsive to a control signal from a remote transmitter;

at least one battery;

at least one motor being supplied with current from the at least one battery responsive to signals provided from the receiver, the at least one wheel being controllably driven by the at least one motor;

a fan drive motor being supplied with current from the at least one battery;

a fan driven by the fan drive motor, wherein the fan draws air from an intake duct between the undersurface of the chassis and the surface into a fan duct, the undersurface of the chassis being larger in area than the area of the fan duct, a differential pressure between a pressure of the air flowing into the fan and a pressure of ambient air inducing a force urging the chassis toward the surface when the vehicle is placed on the surface with the at least one wheel in contact with the surface and the fan is operational, the intake duct comprising an entry portion configured to receive the air, a transition portion configured to transport the air, and an exit portion configured to exit the air to the fan duct, the intake duct being structurally smooth from the entry portion to at least a location vertically below the fan duct when the toy vehicle is placed on ground.

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